Magnetosphere-Ionosphere Coupling Studies Using the PSWS Magnetometer Network

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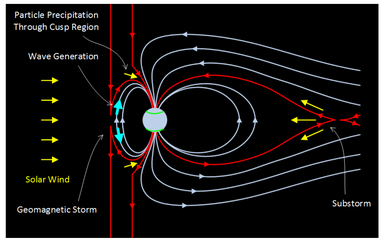
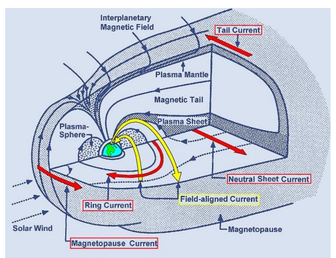
Introduction

- As part of HamSCI Personal Space Weather Station (PSWS) project, magnetometers which measure magnetic field strength and direction, are designed to provide quantitative and qualitative measurements of the geospace environment from the ground for both scientific and operational purposes at a cost that will allow for crowd-sourced data contributions.
- Data from the PSWS network will combine these magnetometer measurements with high frequency (HF, 3-30 MHz) radio observations to monitor large-scale current systems and ionospheric disturbances.
- A densely-spaced magnetometer array, once established, will demonstrate their space weather monitoring capability to an unprecedented spatial extent.
- The primary goals are 1) to provide the general context of geomagnetic activity during the HF experiments; 2) to estimate ionospheric currents at mid/high latitudes; 3) to measure ultra low frequency (ULF) waves; 4) to measure space weather-related disturbances (dB/dt).

Solar Wind–Magnetosphere-Ionosphere Coupling



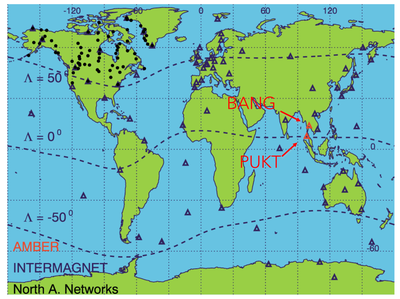
- The Sun and the Earth are connected via magnetic fields, creating a unique geomagnetic field structure: the **Earth's Magnetosphere.**
- The outflow of the solar wind from the sun's atmosphere and its interaction with the earth's magnetic environment and human technologies: "space weather".



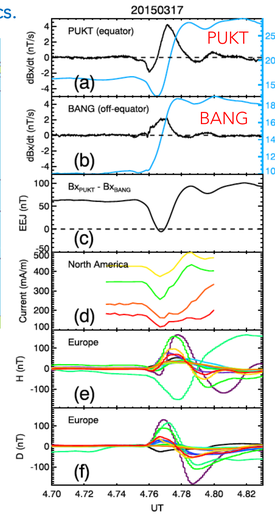
- Space weather is affected by a variety of the ***current systems*** in Geospace.
- The currents are often observed by ***magnetometers*** in space and on the ground.

Science Example: Geomagnetic Induced Currents (GIC) at Mid/Low Latitudes

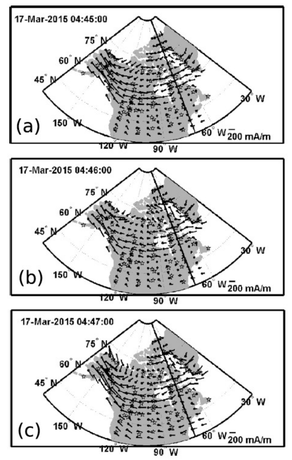
From Carter et al. (2016), Geomagnetically induced currents around the world during the 17 March 2015 storm, J. Geophysical Research: Space Physics.



- The locations of the INTERMAGNET (International Real-Time Magnetic Observatory Network, blue), AMBER (African Meridian B-Field Education and Research, orange) and North American (black points) magnetometer stations.
- The dashed lines indicate the magnetic latitudes 0° and ±50°.



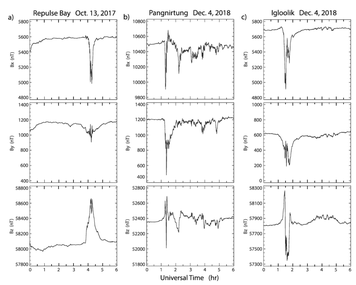
- The Bx (blue) and dBx/dt (black) data for (a) PUKT and (b) BANG stations during the storm sudden commencement (SSC, 0445 UT) event on 17 March 2015, in association with an abrupt increase in the SYM-H index due to the initial interplanetary shock in the solar wind dynamic pressure.



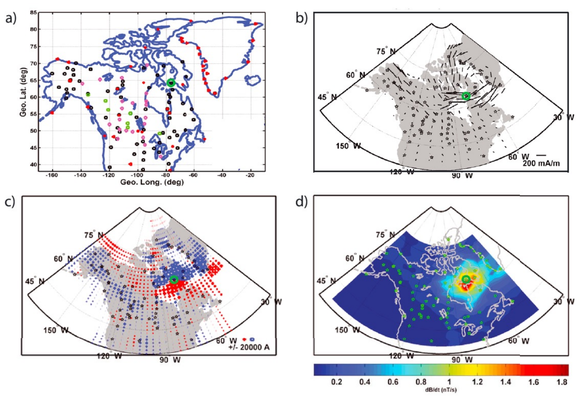
- The ionospheric current vector fields across North America derived from the magnetometer data.
- The eastward ionospheric current strength significantly decreased and then increased to a stronger eastward current in response to the SSC.

Science Example: Geomagnetic Induced Currents (GIC at High Latitudes

From Engebretson et al. (2019), Nighttime magnetic perturbation events observed in Arctic Canada: 1. Survey and statistical analysis. Journal of Geophysical Research: Space Physics.

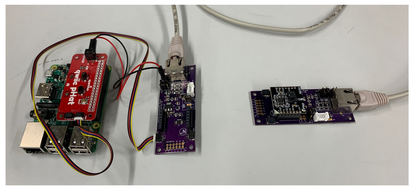


- Large nighttime magnetic perturbations: Repulse Bay 13 October 2017 and Pangnirtung and Igloolik 4 December 2018



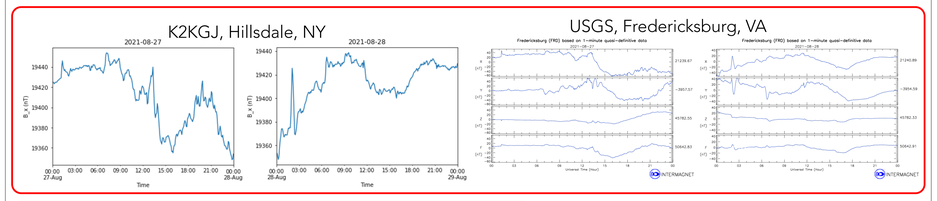
- (a) Map showing the magnetometers used for analysis of 21 large nighttime magnetic perturbation events observed at Cape Dorset from mid-2014 through 2016.
- (b) Median values of equivalent ionospheric currents derived from the magnetometer data.
- (c) Inferred field-aligned currents
- (d) horizontal components of the dB/dt in nT/s.
- Stars in panels b–d indicate some (but not all) of the stations used in the analysis, and Cape Dorset is marked by an open green circle.

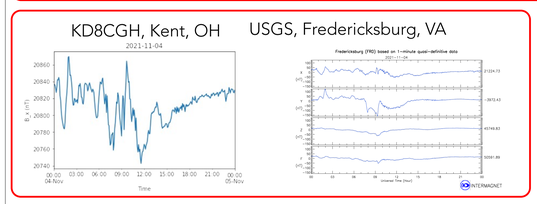
HamSCI Magnetometer



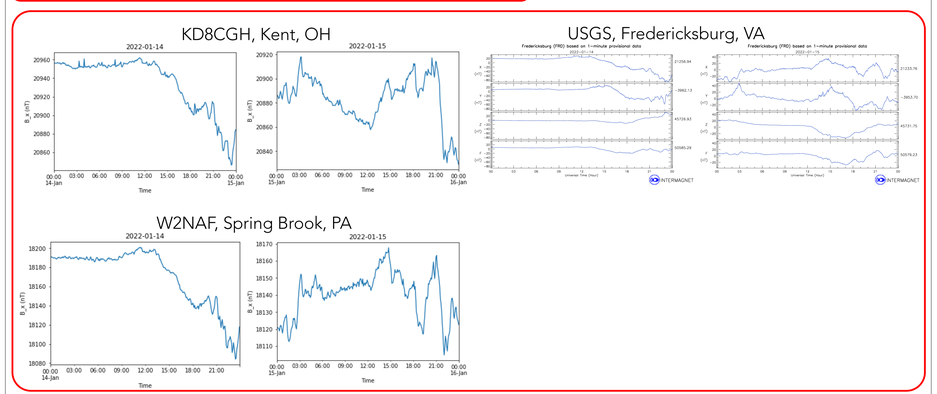
- Magnetic sensor: PNI RM3100, trial-axis, magneto-inductive
- Controller: Raspberry Pi
- Resolution: approx. 6 nT at a 1 Hz sample rate.

- Sensor housing installed on the ground.
- The following example events are chosen during active geomagnetic times (Dst ~ 100 nT).





- Data from the INTERMAGNET Magnetometer (USGS), a highly accurately calibrated science-grade sensor, are also shown for comparison



Conclusion

- Data from a low-cost, magneto-inductive type magnetometer for the HamSCI PSWS project are presented and compared with a professional, science-grade magnetometer nearby.
- The HamSCI magnetometers successfully observed space weather-related phenomena, demonstrating that the its performance is very adequate for scientific investigations.
- Once established, the proposed closely-spaced magnetometer network will provide quantitative and qualitative measurements of the geospace environment from the ground for both scientific and operational purposes at a cost that will allow for crowd-sourced data contributions.

Acknowledgements
The work at the New Jersey Institute of Technology was supported by NSF under grants AGS-2002278/121602. The authors would like thank the HamSCI members for installing the magnetometers and providing data.